Solar Energy Technology
Prof. V. V. Satyamurty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 42
Summary (Contd…)

Last time we have been summarizing whatever we covered in this course that far and we shall continue with that summary if you recall right, we were summarizing up to concentrating collectors.

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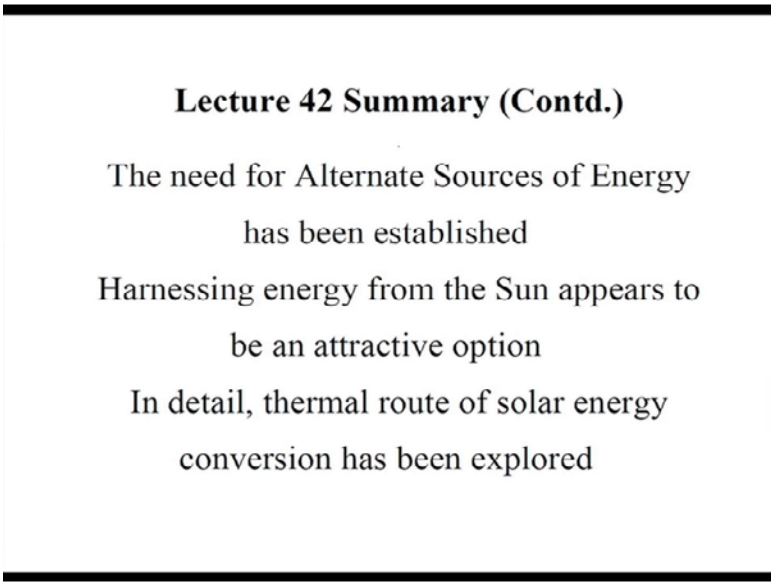

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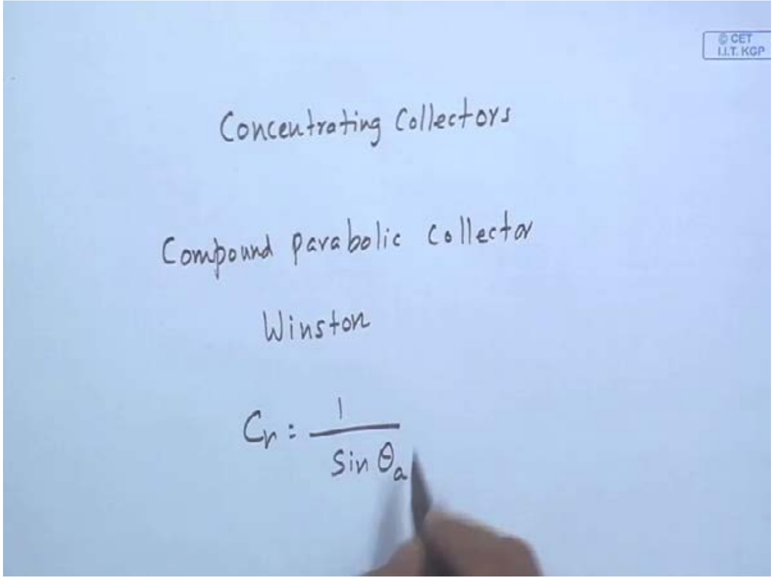

In this process particularly on the topic of concentrating collectors, we have defined concentration ratio and the need for concentration, and then we obtain an expressions for maximum possible concentration ratio, and the angles of incidence for different modes of tracking and the r v that is that is the tilde factor instantaneous to estimate the solar radiation direct on the concentrating aperture, optical efficiency. And then we have expressed the daily radiation received by the concentrating collectors, aperture area. Then we have considered subsequently the compound parabolic collector; this is originally proposed by Professor Winston it is also called as Winston collector.

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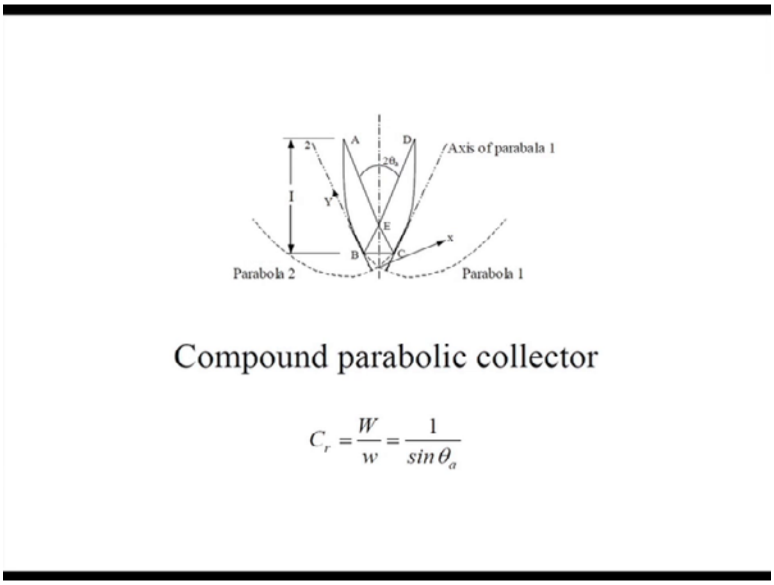

And the focus of the parabola 1 is at parabola 2's intersection point and vice versa as you can see over here. So, whatever is the solar radiation enters in the aperture A D will be having multiple reflections reaching one of the focal points there by transporting heat to the chop with a (( )) arrangement between B and C B is the focal point of parabola 1 and C is the focal point of parabola 2. And concentration ratio is 1 up on sign theta a where theta a is the half acceptance angle. In other words the solar rays beyond the angle of incidence between theta a and beyond that they will not they enter, but they reflect backwards they do not reach the absorbing surface.

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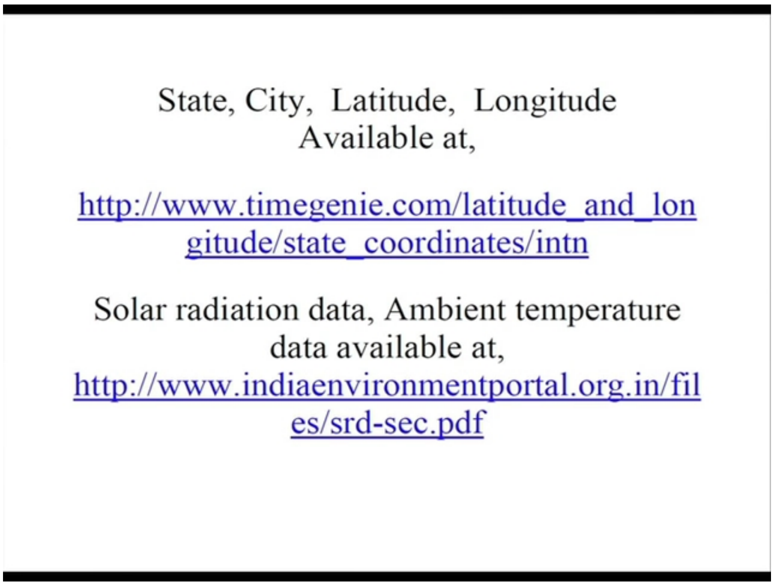

And then we briefly consider the to solve some problems a state city latitude longitude are available at the website given. Similarly, sufficient solar radiation data for the Indian locations is available at the other web site which is shown over here.

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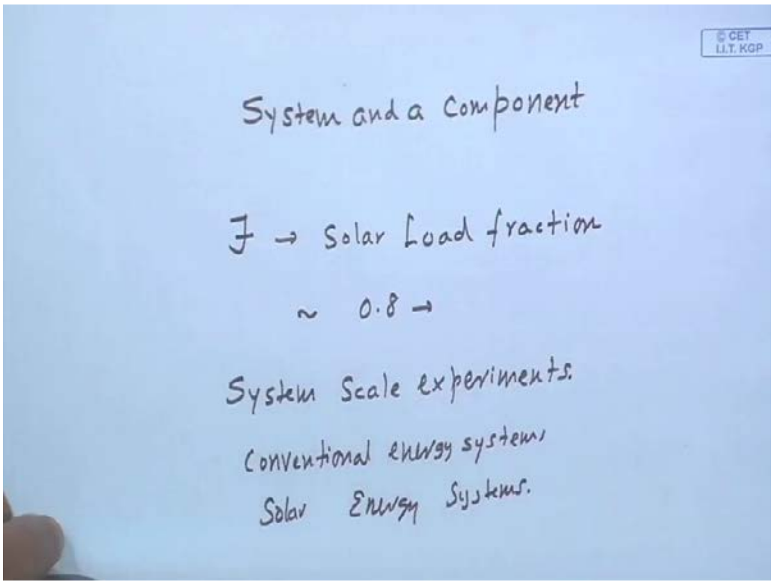

And then we distinguish between a system and a component. Solar collector is only a component in the system, and the system consists of several other components like storage tank, pump controls, heat exchanges and pipes and their associated losses or the heat exchanger penalties which makes the performance of the system different as compared to the just the performance of the solar collector so far which we have been doing.

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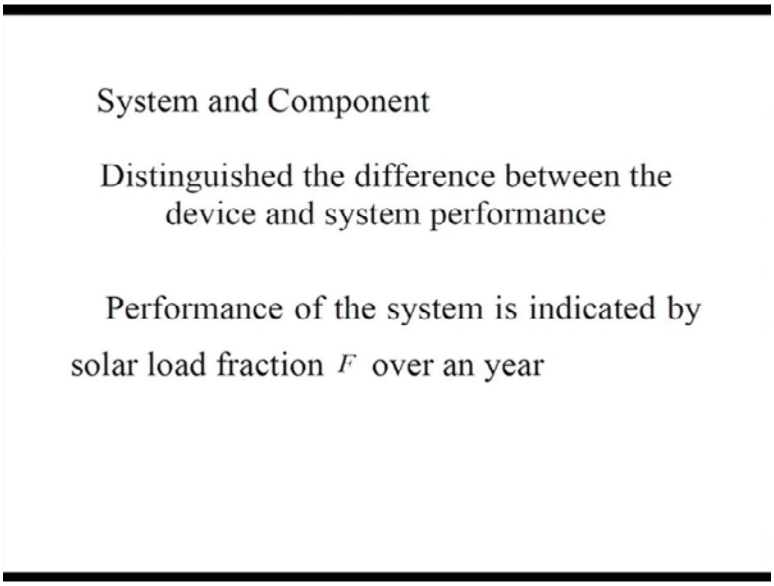

So, this is indicated unlike by a conventional efficiency for a conventional energy system we indicate by solar load fraction F, it is the fraction of the load on the solar energy system that is met by the solar energy. If a particular space heating application is considered for example, on a house and if has got a 192 giga joules of yearly load out of which a 180 or 150 giga joules are met by the solar system this solar load fraction will be approximately 0.8 or 0.7.

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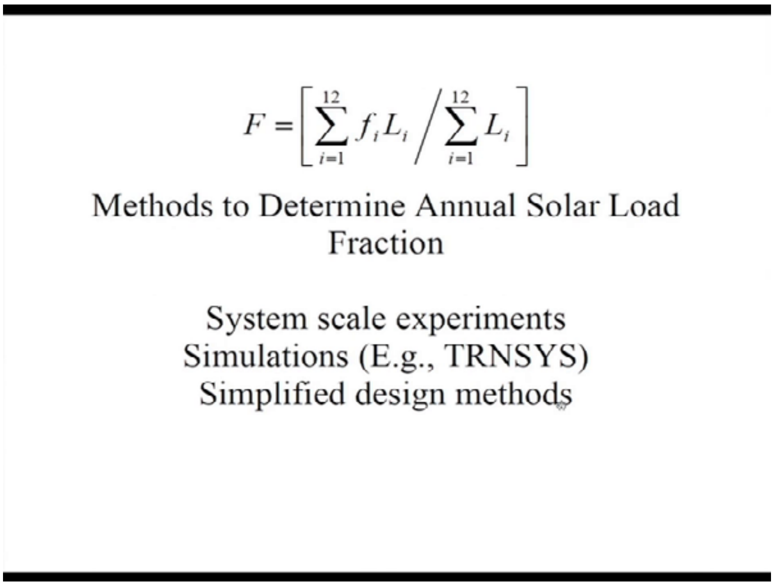

So, the cycle of period has been chosen to be 1 year because the methodological cycle repeats itself and also 1 year is a good period for economic analysis. Now, the whole objective of this course had been finally, to determine the solar annual load fraction and first possibility is system scale experiments. Here is where we recognize the difference between the conventional energy systems or for that matter any component and the solar energy. A conventional energy system, but for minor differences is likely to perform similarly given the same input where ever it is located where as the solar energy system utility, utilizability of the energy separate by the solar energy system, will be different depending upon the location. If you’re having a space heating application in a cold location like Srinagar, Kashmir and you want to use it for in Chennai probably there may be no space heating requirement at all and system scale experiments are expensive time taking.

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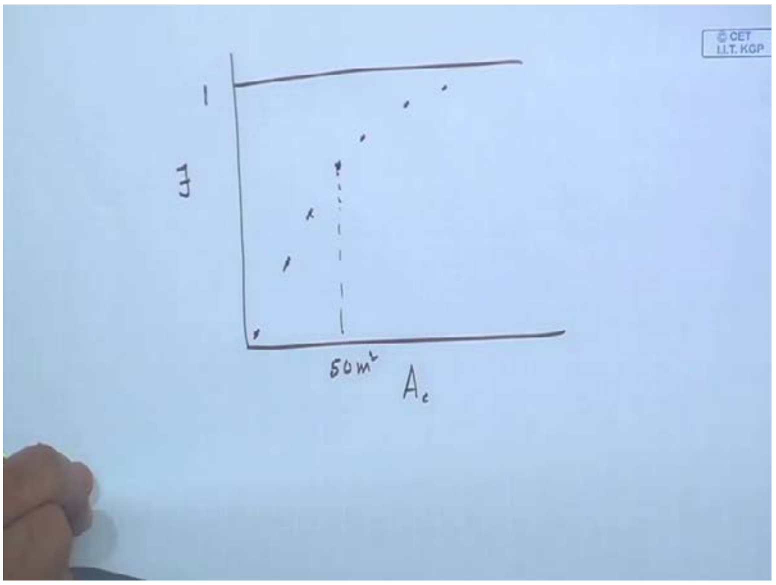

And as you recall, if you plot the solar load fraction verses area of the curve or a period of one year. If you start with let us say an area of 50 square meters with a certain orientation then you will get 1 point. Now, another point another year another point like that and possibly you may do with 5 6 points and obtain the curve this may be 1. Now the whole point is optimization of the system parameters will take probability long time if somebody wants to change the slope, floret, storage, capacity heat exchange effectiveness then again this has to be performed. So, if you want to get in a minimum time period you may have to get several systems of different areas operating simultaneously along with different orientations different slopes heat exchange seizers it's expensive.

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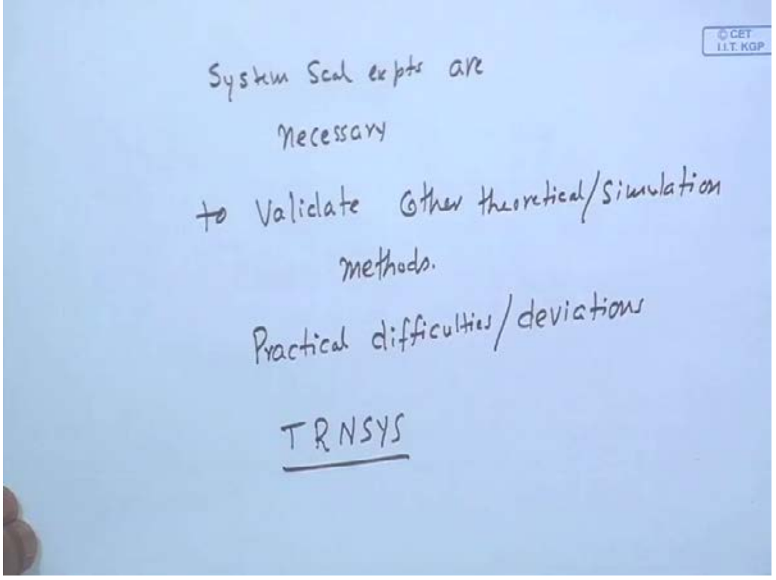

Never the less this system scale experiments are necessary to for example, validate other possibly theoretical or simulations. Then also practical difficulties and deviations from our assumptions and approximations; so trances is one such modular similar simulation program, which has been developed at the University of Vesconson and it has got several components like a flat plate collector consolidating collector different modes of tracking trombe wall passive systems etcetera radiation processor metallurgic processor and several other components. So, one can link up the required components and obtain the solar energy performance over a system and change the fluorite or any of the other parameters associated with this system and obtain the performance of dranutily very short time compared to system scale expectance.

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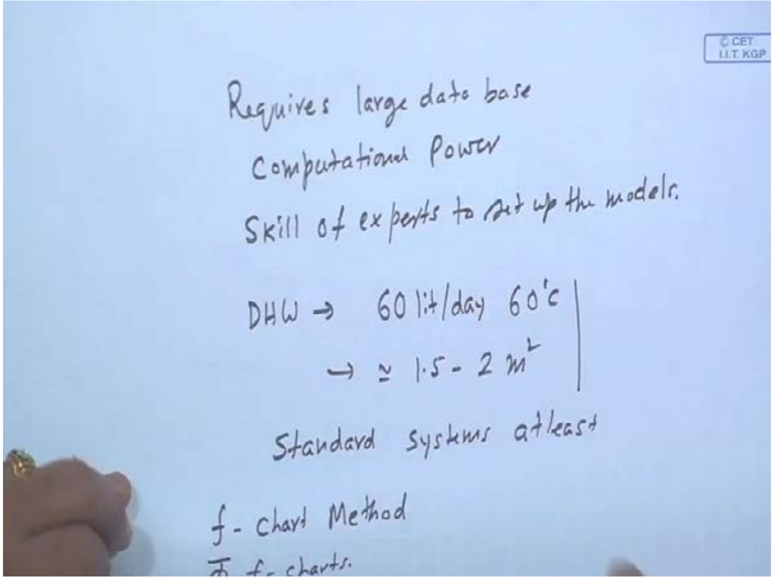

So, this is however, this also has got certain limitations requires large database, computational power and perhaps the skill of experts set up the models for the components. And while this is certainly justified and while this is certainly practically meaningful compared to system scalar experiment for larger systems if you have a domestic hot water system D H W may be in the Indian context supplying about 60 liters per day at let us say 60 degrees c this may require approximately 1.5 to 2 meter square of collector area with a standard storage tank of 70 liters capacity or 75 liters capacity. And this may be about 20000 rupees.

Now, simulations almost cause the same thing weather it is a large system or a small systems. So, at times even the simulation cost may not be may be too much for a small system further the need of the industry is to have a quickly calculable implement able relation to obtain the sizing of the solar energy system needed which will be reasonably take into account the location dependence and for standard systems at least. So, the f chart method and the phi bar f chart method once again developed at the University of Vesconson have been popularly called as simplified design methods.

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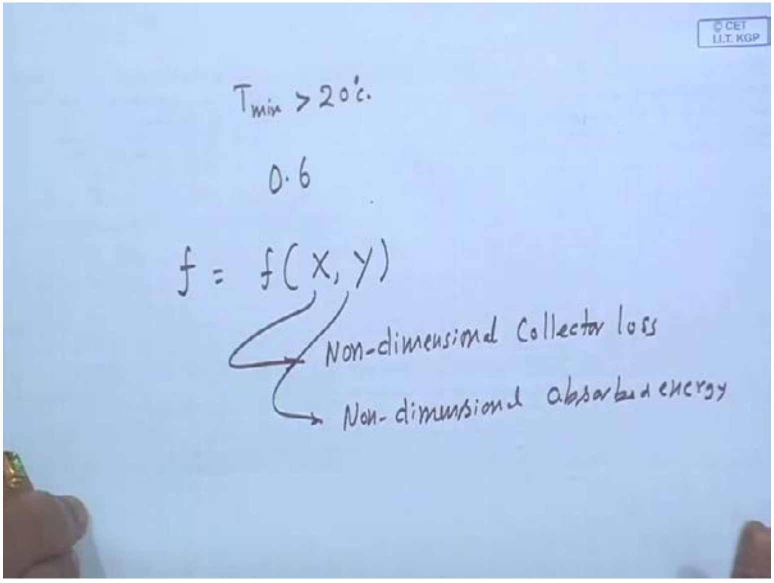

This f chart method is applicable for t minimum. So, if this supply of energy is above 20 degree c you can apply f chart method and the correlation has been developed for certain ranges of the parameters which have been listed over here 0.6 to 0.9 (( )) for normal.

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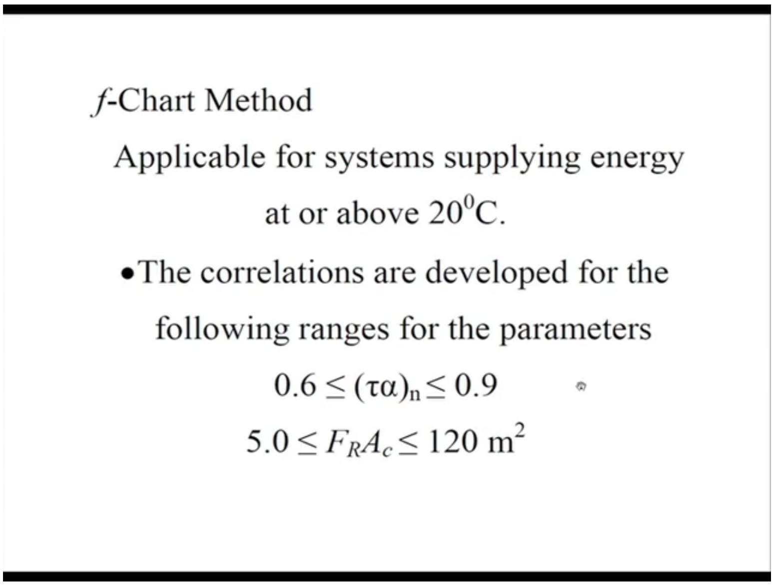

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$$2.1 \leq U_L \leq 8.3 \text{ W/(m}^2\,{}^{o}\text{C)}$$

$$30 \leq \beta \leq 90^{o}$$

$$83 \leq (UA)_h \leq 667 \text{ W/(}^{o}\text{C)}$$

X is the non-dimensional collector loss

$$X = \frac{F_R U_L \left(100 - \bar{T}_a\right) \Delta\tau\, A_C}{L}$$

Y is the non-dimensional absorbed energy

Similarly, area over all loss coefficient, slope and the building loss coefficient which we have explained in the detail lecture. So, this f has been correlated as a function of 2 non dimensional parameters 1 the non dimensional collector loss, and the non dimensional absorbed energy both on a monthly basis. So, X is defined over here as F R U L into 100 minus T a bar into the number of seconds in the month into the area upon the load if U L is in watts per meter square degree c l will be in joules.

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$$Y = \frac{F_R \left(\overline{\tau\alpha}\right) \overline{H}_T N A_C}{L}$$

F_R is the collector heat removal factor,

$\left(\overline{\tau\alpha}\right)$ is the monthly average daily transmittance absorptance product

U_L is the collector heat loss coefficient, $\text{W/(m}^2\,{}^{o}\text{C)}$

So similarly, Y is F R monthly average transfer of certain product tau alpha bar and the monthly average d radiation on the tilde collector surface, multiplied by the number of days in the month, and the area of collector and if H d bar is in joules per meter square day L also be in joules of course, you know the other meanings and. So, these are all explained for your convenience once again here repetition.

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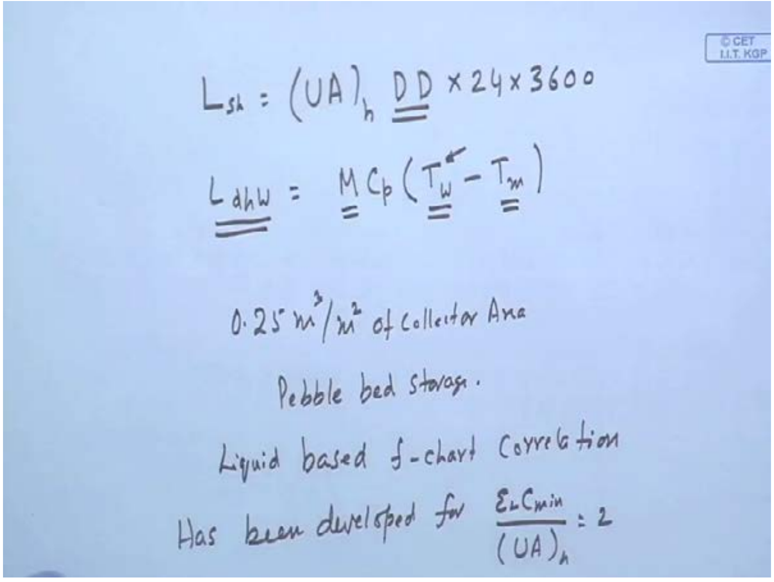

And calculation of load space heating load is in terms of the building loss coefficient multiplied by the degree days, multiplied by 24 into 3600. Basically degree days means the deficiency or the actual ambient temperature being lower than the a comfort condition like 20 degree c or so. The defecity is indicated by degree day irrespective of the method of evaluation. And then domestic hot water requirement load will be mass of the water that you require multiplied by specific heat into mains temp T w minus T m the temperature at which what is desired minus the temperature of the mains this apply temperature.

Let us, also clarify this T w has nothing to do with that T minimum of 20 c. 20 c and above is acceptable to us, and T w is the set point temperature and if you compare with a conventional gazer you may set the thermostatic at 60 or 50 or 40. So, this T w is something like this which is used to estimate only the load not to be confused that the solar energy system is going to supply at T w. So, the amount of energy saved will depend upon how much of mass of the water is delivered by the solar energy system, and at what average temperature or instantaneous temperature, one can estimate and compared to the total amount of domestic hot water load that will be the fraction met by the solar energy system. So, the relations once again f for the air systems is given over here first 1 and there are corrections for x.

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$$\frac{X_c}{X} = \left(\frac{Actual\text{ storage capacity}}{S\tan dard\text{ storage capacity}}\right)^{-0.30}$$

Liquid Based systems

$$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$$

$$\frac{X_c}{X} = \left(\frac{Actual\ storage\ capacity}{S\tan dard\ storage\ capacity}\right)^{-0.25}$$

Valid for, $0.5 < \left(\frac{Actual\ storage\ capacity}{S\tan dard\ storage\ capacity}\right) < 4.0$

$$\frac{Y_c}{Y} = 0.39 + 0.65\exp[-0.139(UA)_h/\varepsilon_L C_{\min}]$$

If the flow rate is different from the standard flow rate of 10 liters per second per meter square of the collector area and then you have got a correction for the storage actual storage capacity by the standard storage raise to the power minus point 30 and the standard storage in this case is point 25 meter cube per meter square of collector area pebbles. A pebble bed storage is usually used for air systems. So, similar relation is given for the liquid base systems these numbers 1 point o 4 1 point o 2 9 they slightly differ and you have got X c upon X if this storage capacity is different from the standard storage capacity to correct X and this relation is valid between point 5 to 4 of the ratio of actual storage capacity to the standard storage capacity. And then the liquid based f chart correlation has been developed for epsilon L C minimum by U A h is equal to 2 epsilon C minimum by U h equal to 2.

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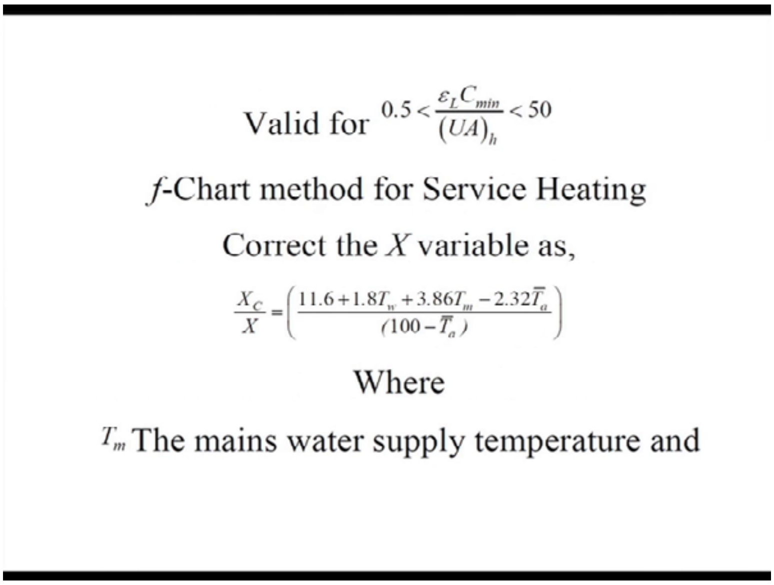

So, if the heat exchanger is larger or smaller leper form should be slightly different and again the f chart variable x is corrected depending up on the actual size or effectiveness of the heat exchanger.

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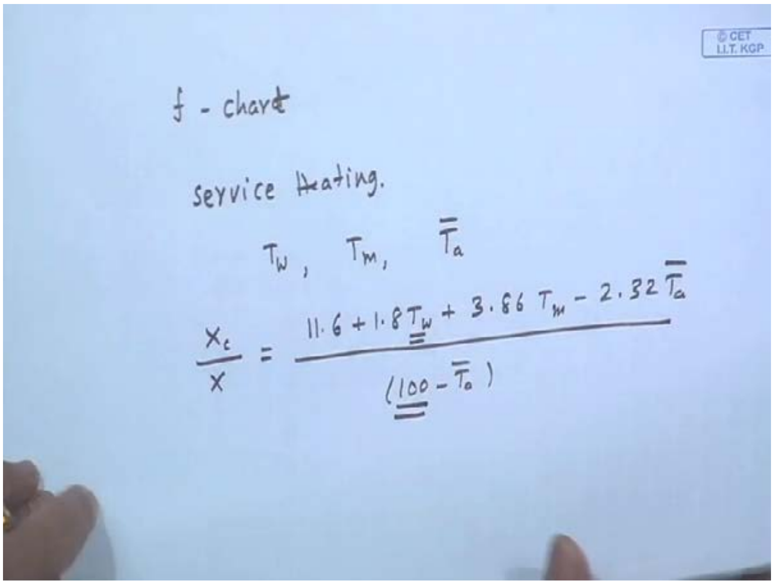

Then f chart has been made useful for service heating that is you would like to estimate the solar load fraction if the system is going to supply at some T w. If the mains temperature is T m and the ambient temperature is T a bar. So, that is simply done using the 8 collector correlation or the water collector correlation liquid based system, as X c by X is equal to 11 point 6 plus 1 point 8 T w, plus 3 point 8 6 T m minus 2 point 3 2 T a bar upon 100 minus T a bar. So, you change the X coordinate depending upon T w and you have a service water heating system where T m is the mains temperature and T a bar is the ambient temperature the monthly average daily ambient temperature. Once again, I have emphasized this 100 as absolutely nothing to do with the boiling point of water this only a scaling factor in defining x so T w the minimum acceptable hot water temperature.

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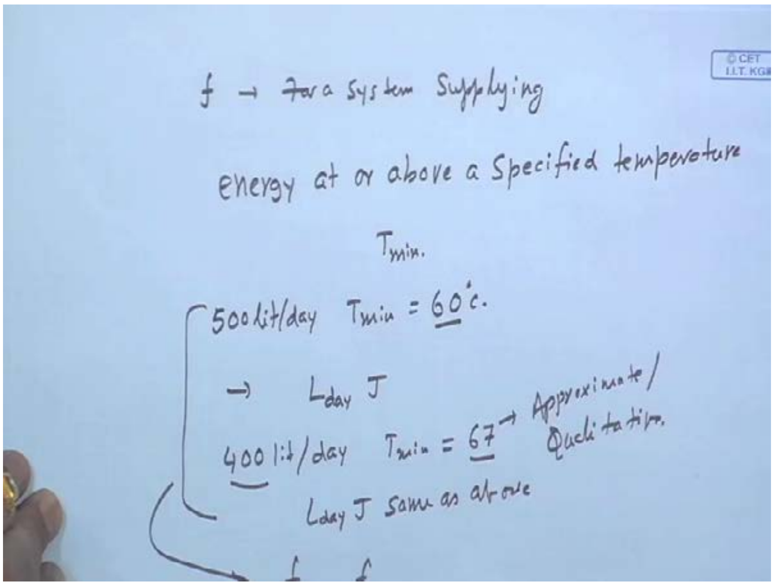

Now in order that you calculate the solar load fraction f for a system supplying energy at or above a specified temperature that temperature being t minimum. So, now, the you might say that you want 500 liters per day at T minimum 60 degree c. So, this may be so many loading joules or this may be 400 liters per day at T minimum may be 67 l day in joules same as above. Lower capacity higher temperature, so I did not because there will be a mains temperature involving I did not directly proportionate it this is some sort of a qualitative approximate and qualitative not that I have calculated this number, but I know we know that 60 this 67 that this T minimum should be higher than this since the capacity is less for a given load. The contention is load fraction will be f 1 and f 2 even though the load required on the load of the system is the same if it is being supplied at 60 degree centigrade my solar load fraction will be something and if it is supplying at a minimum of 67 degrees the solar load fraction differs.

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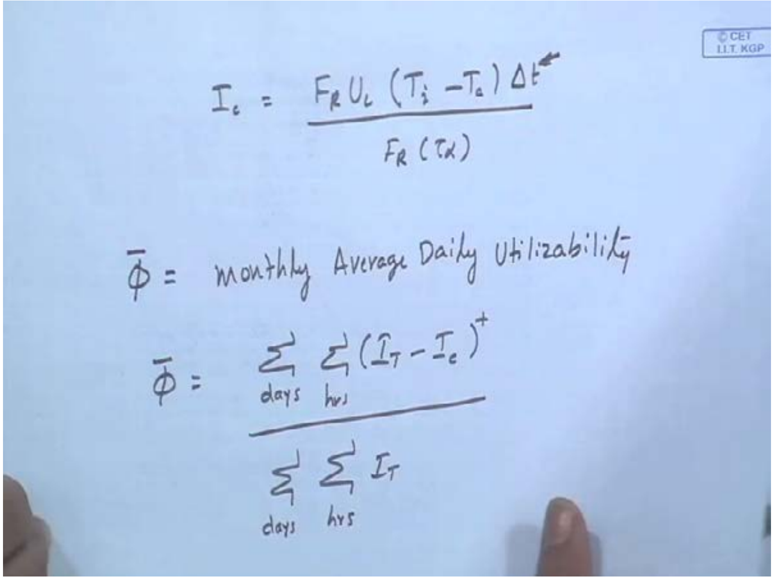

So, we have already introduced the critical level critical solar radiation level I c as F R which corresponds to useful energy being 0 in other words the solar radiation falling on the collector surface is just sufficient to meet the losses corresponding to that temperature.

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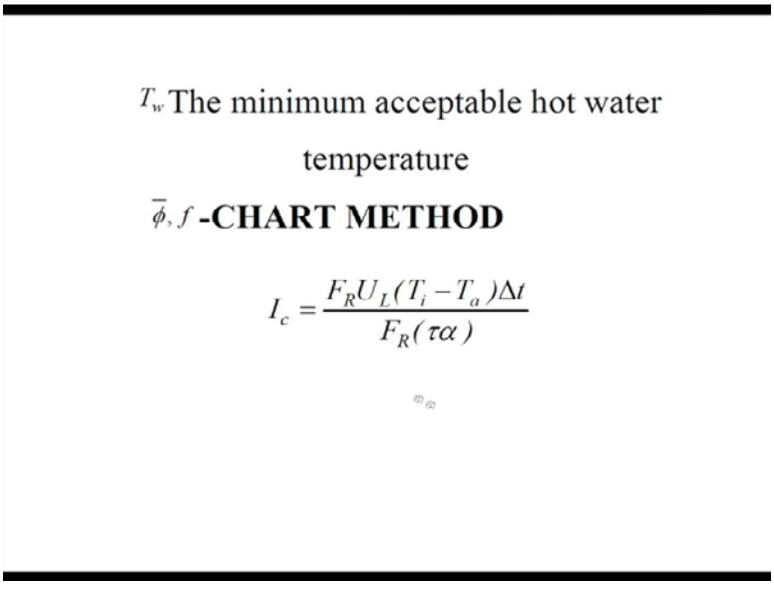

This on a instantaneous basis if T i is the inlet temperature then I c will be given by this including this time factor delta t. So, if I define what I call the monthly average daily radiate utilizability monthly average daily utilizability let me write it because it is a tongue twister monthly average daily utilizability. So, basically phi bar is the ratio of solar radiation available above the critical level upon the total solar radiation falling on the collector surface. So, if I T is the solar radiation for any given hour and I c is the corresponding hourly scale critical radiation, when this is positive there is some supply of energy and I sum up all these when it is negative I treat it has 0 that is the meaning of the superscript plus meaning if the solar radiation falling on the collector is less than the critical solar radiation level the pump is shut of and we do not intend to cool the fluid. So, this is a good indicator of how much of solar radiation is available to you to supply the quality of energy that you desired.

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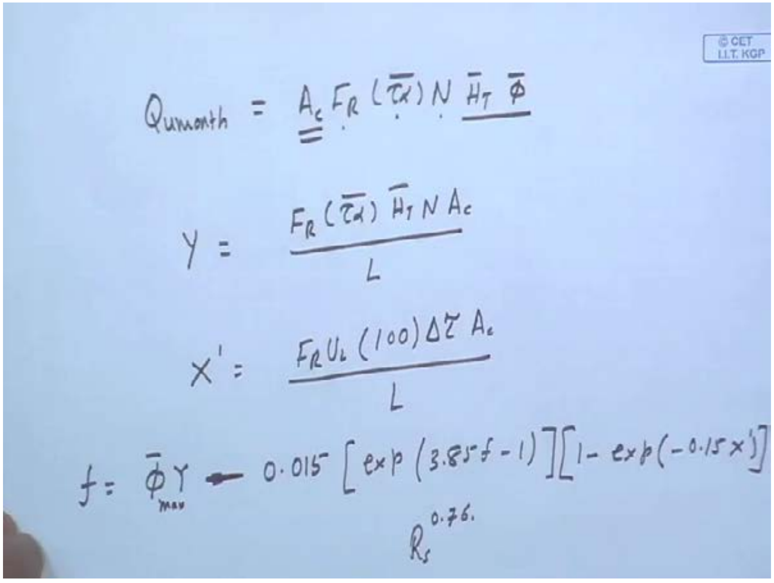

So, a roughly if I don’t bother about losses and other system parameters if you want to have a (( )) value of the useful energy that the solar energy system is going to supply over the month will be area of the collectors multiplied by F R tau alpha bar multiplied by the number days into the monthly average daily radiation on the tilde surface times monthly average daily utilizability. So, this is the solar radiation available above the critical level multiplied by the number of days and optical efficiency and the heat remover factor of the collector being proportion to the area of the collector.

So, we define y the same as we define for the case of f chart f for tau alpha bar H T bar and A c by L and then X is slightly modified and called x dashed F R U L times 100 instead of 100 minus d a bar we got rid of this d a bar and just put it in terms of 100 again just a scaling factor multiplied by A c. So, that x dashed and y will be comparable orders of magnitude a correlation will be generally a good correlation if you have more or less all the variables are comparable orders of magnitude. Instead of something one of them is 10 to the power of 6 and other is minus 10 to the power minus 3. The effect of that variable in this scale of 10 to the power of minus 3 shall not be recognized or in general in any other calculations by the load l. So, you have got after number of simulations claimed under this have correlated the monthly solar load fraction to phi bar max y I will tell you why it is called max minus 0.015 exponential 3.85 f this I am rewriting to just say that it is a 1 minus e x p minus 0.15 x dashed times R s to the power 0.76 where R s is the ratio of standard storage to the actual storage.

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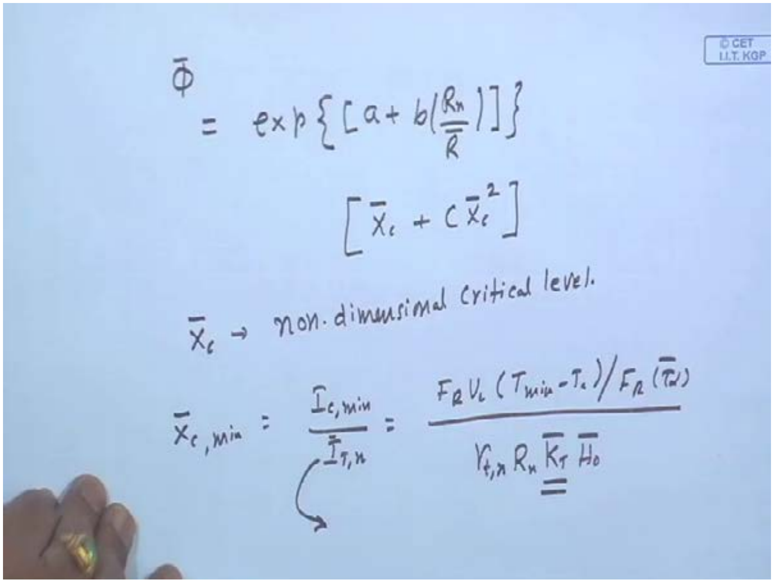

So, the correlation contains the effect of this storage now phi bar is a metallurgic statistic which combines with the operation condition. So, given a location and the solar radiation distribution from day to day if the system is supplying energy at 60 degrees 50 degrees 70 degrees the solar radiation available to you above the critical level will be different. So, phi bar will be different. So, this is a good indicator of combining the metallurgical statistic and the operating parameter the main one being the critical radiation level or the temperature at which you desire the energy delivery this has been correlated by clain as exponential a plus b R n upon R bar times X c bar plus C X c bar square where X c bar is the non dimensional critical level which we have defined we should go into non dimensional critical level and a b c are defined in terms of the clear this index.

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$$\overline{X}_{C,min} = \frac{I_{c,min}}{I_{T,n}} = \frac{\left[F_R U_L \left(T_{min} - \overline{T}_a\right) / F_R \left(\overline{\tau\alpha}\right)\right]}{\left[r_{t,n} R_n \overline{K}_T \overline{H}_o\right]}$$

$$a = 2.943 - 9.271\overline{K}_T + 4.031\overline{K}_T^2$$

$$b = -4.345 + 8.853\overline{K}_T - 3.602\overline{K}_T^2$$

$$c = -0.170 - 0.306\overline{K}_T + 2.936\overline{K}_T^2$$

$$R_n = \left(1 - \frac{r_{d,n} H_d}{r_{t,n} H}\right) R_{b,n} + \left(\frac{r_{d,n} H_d}{r_{t,n} H}\right)\left(\frac{1+\cos\beta}{2}\right) + \rho\left(\frac{1-\cos\beta}{2}\right)$$

Of course, as such X c bar which I call it minimum if I write it in terms of I c minimum compared to T minimum this is nothing, but the critical radiation level I have not written the time factor note this by r t at noon time R at noon time K T bar H 0 bar this is the solar radiation on the monthly average day at the noon time with which I am comparing the critical radiation level. So, this can be more than 1 or less than 1. So, this is because this is an average level it would be solar radiation will be higher or on this with K T greater than K T bar. So, there will be useful energy gain even X c bar is greater than 1. So, that is what you should remember you should not think that the noon time solar radiation is reached and hence there will be no more useful energy above that level, but this is based upon the average day of the month.

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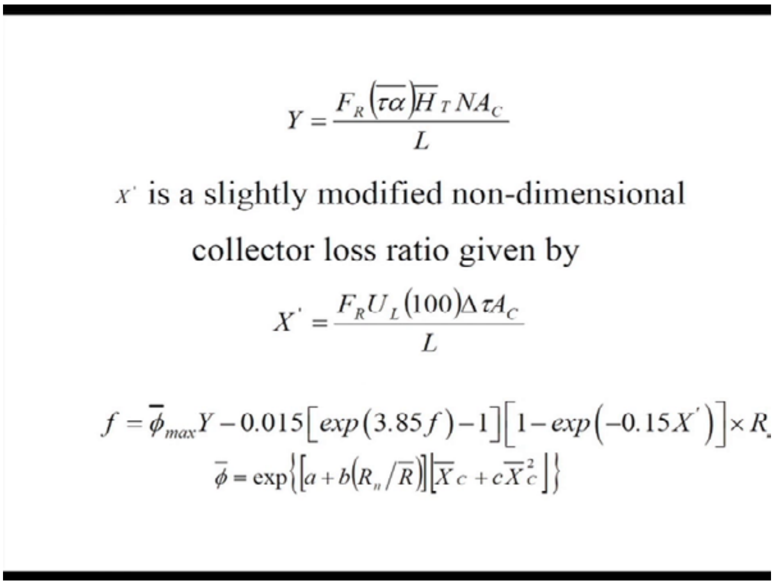

So, the constants a b c are correlated in terms of the clearness index and then the other parameter which you have to see in the phi bar correlation is where did I write that.

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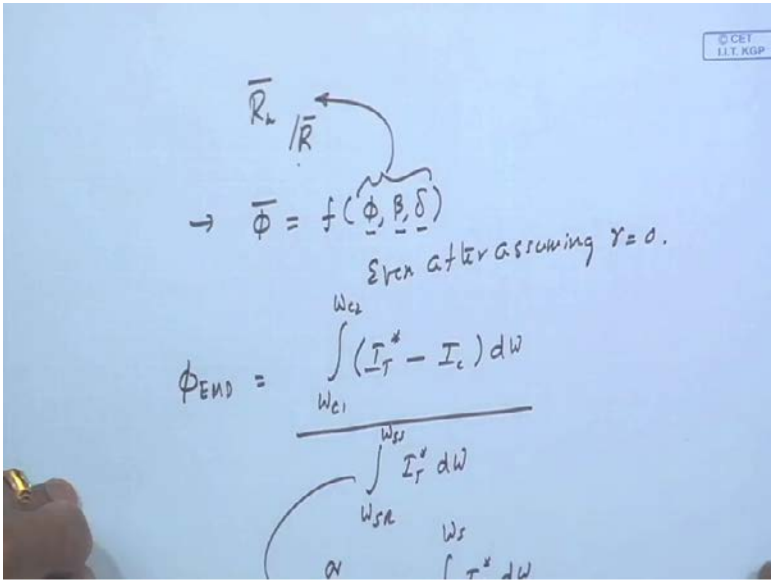

This R n by R bar in general I can expect phi bar in addition to X c bar function of phi beta delta and even assuming even after gamma equal to 0. So, first of all this correlation is valid only for south facing surfaces and then it should be a function of the latitude, slope and declination in general these three have been combined into 1 parameter R n by r bar because this is sort of a stretching factor at the noon time compare to the stretching factor over the overall day would should take into account the latitude slope declaration combination R n again we have expressed a large number of times in the problems in the derivation this is it is 1 minus I d by I into R b at the noon time this is I d by I times 1 plus cos beta by 2 into 1 minus cos beta by 2 into ground reflectivity rho.

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$$\phi_{EMD} = \frac{\int_{\omega_{c1}}^{\omega_{c2}} (I_T^* - I_c)\, d\omega}{\int_{\omega_{sr}}^{\omega_{ss}} I_T^*\, d\omega}$$

$$I_T^*(\omega_{c1}) = I_T^*(\omega_{c2}) = I_c$$

$$\overline{\phi}\,\overline{K}_T N \overline{H}_0 \overline{R} = \phi_{EMD} \overline{K}_T^* N_c \overline{H}_0^* \overline{R}^*$$

So, later on a little more general approach has been followed and a equivalent mean day utilizability has been defined as omega c 1 to omega c 2 and I T star the distribution of the solar radiation of the equivalent mean day minus I c integrated between two limits omega c 1 and omega c 2 up on the omega s r to omega s s I T star d omega as a matter of fact it could be minus omega is to plus omega s also or and assuming that you take care of the beam radiation component no certain parts I T star are will be non 0 or only defuse radiation.

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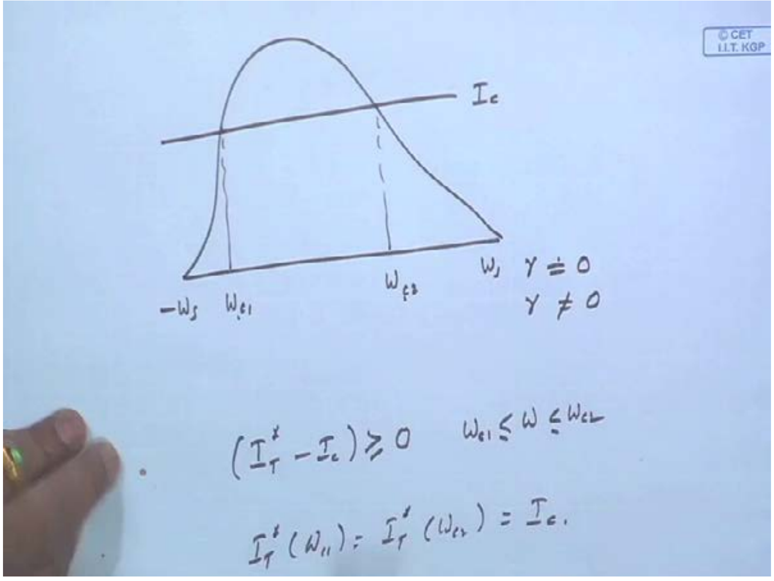

This can be explained this omega c 1 and omega c 2 the critical it need not to be necessarily symmetric gamma can be 0 or gamma need not be equal to 0 minus omega s plus omega s this is I c. So, this will be omega c 1 omega c 2. So, by choosing to integrate between omega c 1 and omega c 2 we do not worry about I T star minus I c is always greater than or equal to 0 in omega c 1 less than omega less than omega c 2. So, it can be separated or one can integrate. In fact, it can be done it has been done. So, this is obtained by I T star omega c 1 equal to I T star at omega c 1 equal to I T star omega c 2 equal to my critical radiation level.

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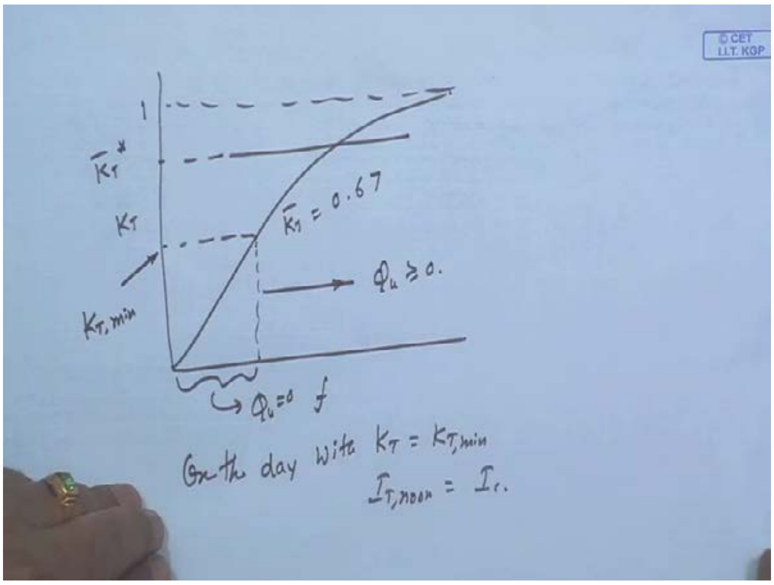

So, that equivalent mean day I have not yet defined what it means is if this is in Lue and Jodankar and is the cumulative frequency K T and this may be approximately one this may be K T bar is equal to 0.67 this is some K T minimum. So, this is on the day with K T equal to K T min I T noon equal to I c. So, these days Q u equal to 0 and these days Q u is greater than or equal to 0.So, I will ignore these days and find out average of the clearness in the system here to here this is my K T bar star.

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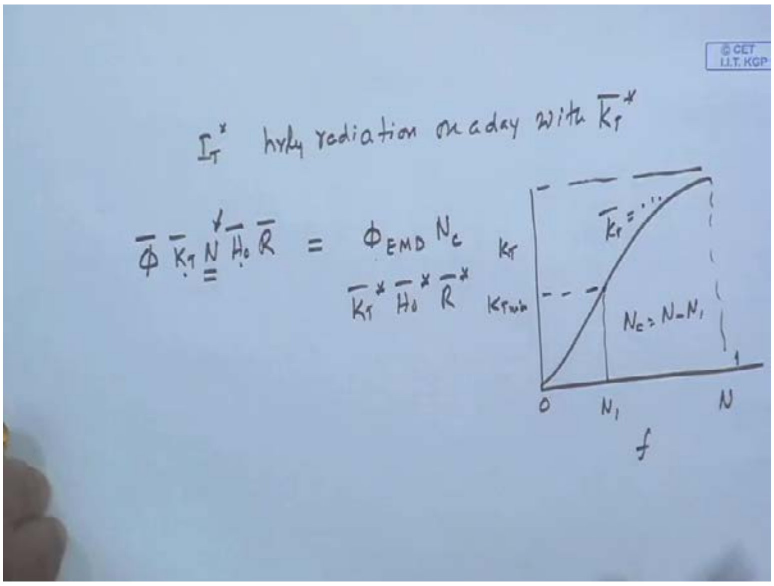

So, I T star hourly radiation on a day with K T bar star we have in detail explained about how to find out this K T minimum by equating the noon time radiation to the I c, you will find out unknown K T that will be the K T minimum. So, the logic is the monthly average useful energy sort of multiplied by K T bar into number of days into H 0 bar into R bar let us look at it what this is H 0 bar into K T bar is H bar, the monthly average daily radiation on a horizontal surface multiplied by R bar on the tilt surface, multiplied by N is the total radiation, multiplied by phi bar is the solar radiation above the critical level based upon all the number of days in the month. That should be equal to no matter though I calculate the E M D then I shall use the number of days N C once again if this is my curve this is N 1 N number of days in the month N C equal to N minus N 1 this is K T min.

So, this is cumulative frequency f this capital K T per a K T bar equal to something right. So, this 0 to 1 can be transformed into N is equal to 1 to 30 or 31. So, I know for simplicity I am writing it in terms of the number of days rather than the cumulative fraction. So, phi M D into N C into K T bar star times H 0 bar star into R bar star what it means is the solar radiation available to you above the critical level based on the multi average daily (( )) and the total radiation for the month over all the days n should be the same as the solar radiation available to you above the critical level on the days of K T beyond K T minimum above K T minimum because for K T less than K T minimum there is no contribution to solar energy that negative contribution is not taken into account in calculating the utilizability.

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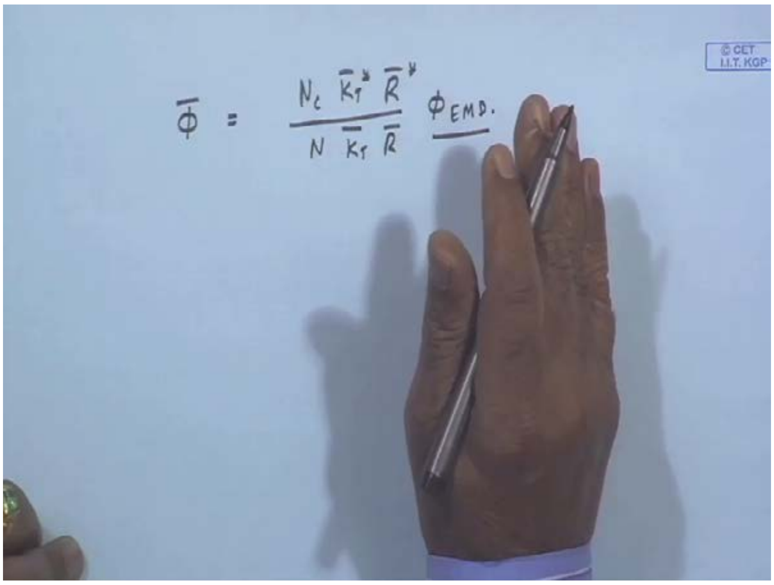

So, that should be the single day E M D utilizability multiplied by the corresponding numbers from this you can easily calculate phi bar if phi M D is known. So, which if have already got phi bar should be simply N c K T bar star R bar star by N K T bar R bar into phi E M D. So, you make a single day calculation you will get the monthly average daily utilizability and this is easy to calculate for a concentrating collector or gamma not equal to 0 expect when the R b factor is complicated not integrable otherwise it can be done and for modes 2 and 3 you can of concentrating collectors strict or you can have a numerical integration procedure to get the phi E M D originally in the phi bar f chart method we did not include the tank losses or the heat exchanger at phi bar f chart correlation does not include tank losses or heat exchanger.

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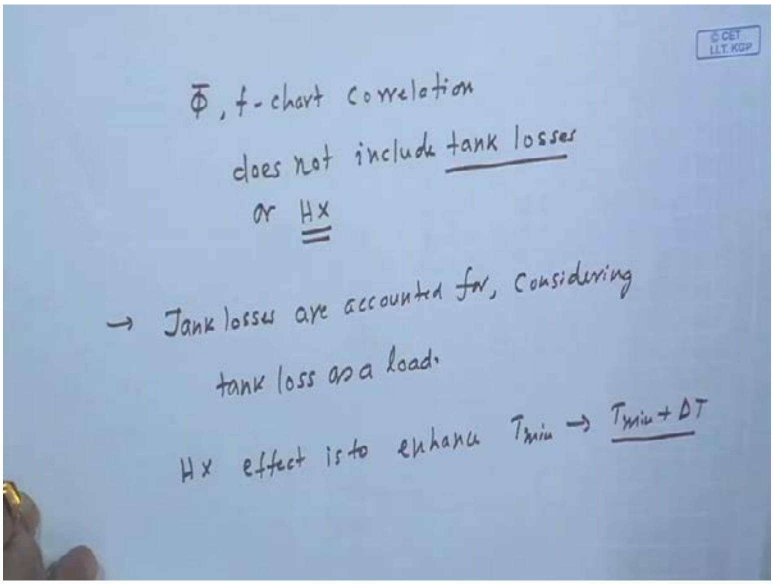

So, that is valid assuming tank losses to be 0 or infinitely large heat exchanger. So, we have devised a I T to schemes to take in to account the tank losses and the heat exchanger the basic philosophy being to account for tank losses or accounted for considering tank loss as a load. So, first you guess a tank temperature and calculate the take losses considered to be a part of the load estimate the phi bar f chart and set up an iterative using the phi bar f chart find out f and set up a iterative scheme to check whether the guess temperature is correct or not.

Similarly, heat exchanger effect is to enhance T minimum to some T minimum plus delta t because there is an certain loss across the heat exchanger or the collector has to supply essentially energy at higher temperature, consequently it is a penalty on the performance of the collector, so you calculate utilizability etcetera assuming T minimum plus delta T as a minimum temperature required in. So, doing you were again with a guest solar load fraction corresponded to this delta T and you set up whether the amount of energy transferred across this delta T by the heat exchanger is equal to the energy as estimated from the solar load fraction and multiplied by the load on this system that will set up the objective function to iterate delta T. Of course, both can be simultaneously take it to an account.

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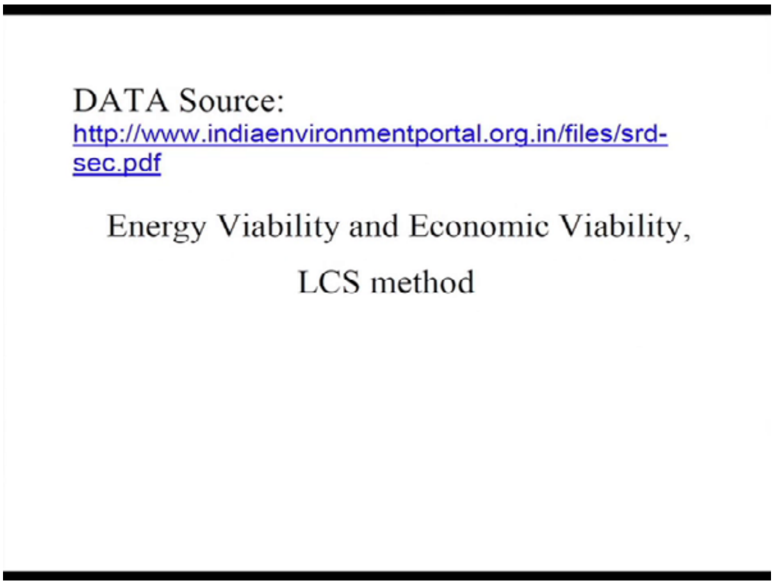

So, then data source of course, they have given of course, at the end of the summery I have given a large number of a http of web with which you can go through and get a lot of method.

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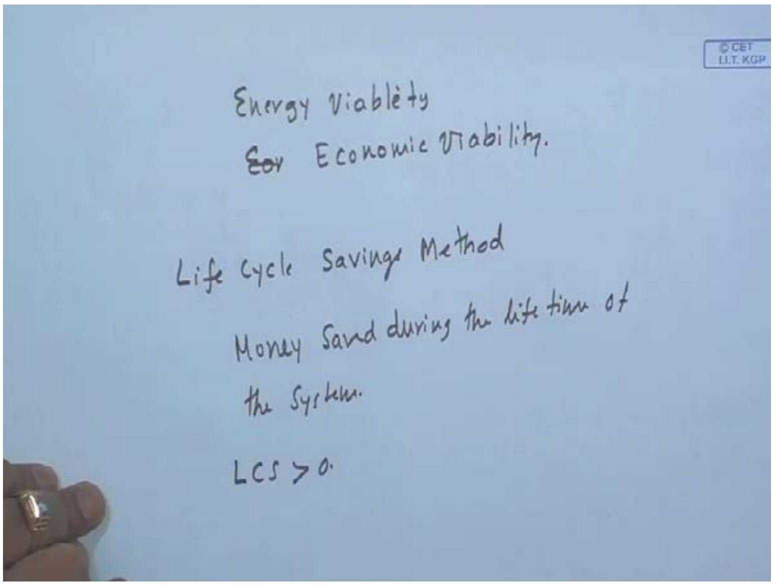

Then we consider energy viability that is during the life time of the in general any alternative system, It should be able to save that much of energy that has been used in making those system and its components. Next is the economical viability. There are several indicators like payback period now you calculate whether if the investment is something like 10000 rupees and you are going to save 2000 rupees then payback period may be per year payback period may 5 years of course, It can be analysis can be complicated by taking into account the inflation of the fuel rate, inflation the depression of the equipment and the bank interest etcetera, etcetera never the less payback period is something which is indicative.

And that should be if it is less than the life cycle or the life time of the energy system or individual system then it is viable otherwise it is not. Normally 2 to 3 years of payback period is acceptable to the industry. Finally, to account for complex scenario we have consider what is called the life cycle savings method in short this is the money saved during life time of the system and if you try to put down all the income mainly due to the saving of energy and tax benefits and government incentives that will come as income and the expenditure could be the repayment of the investment plus, The inflation plus, The interest rate on the bank and the some maintenance plus, Auxiliary power all this thing come under expenses.

So, that is converted into today’s monitory value which is called the present worth factor in the economic terminology and you estimate over a period of 10 years or 15 years or 20 years assuming the life cycle or life time of the solar energy system. So, the minimum condition is the life cycle savings should be positive if it is negative you will not you cannot accept that system.

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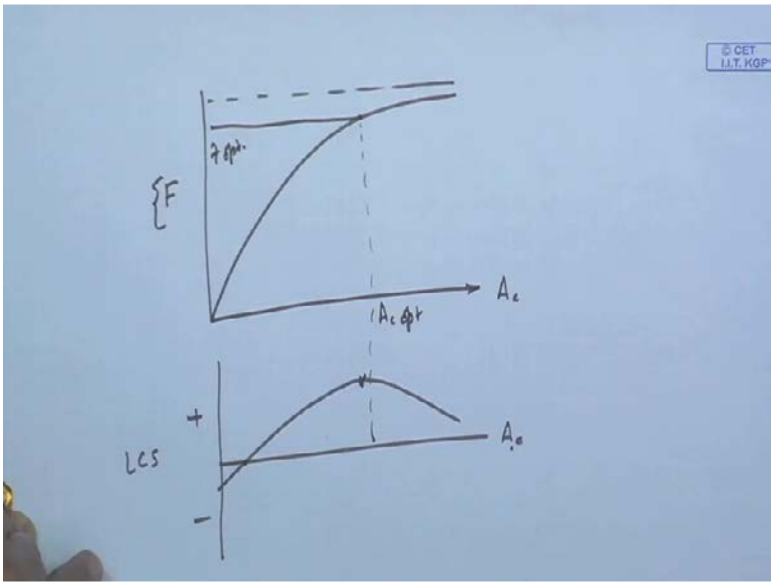

So, that is what it is represented over here if you have got F verses area curve which we have drawn a number of times verses same area verses the life cycle savings positive, negative. This is as mathematical way of saying if area approaches 0 for very, very small areas the energy delivered is almost 0 consequently the saving is 0, but the other expenses will remain because you have got the system components in other word somebody forgot to put the collectors. So, there is a negative life cycle savings it becomes 0 then it starts increasing becomes positive and reaches a maximum, Then starts decreasing because, You need larger and larger areas for smaller and smaller increments in F. So, this is the point which will be my area optimum and the corresponding F optimum. So, we choose the area where the energy delivered is maximum per rupee of investment.

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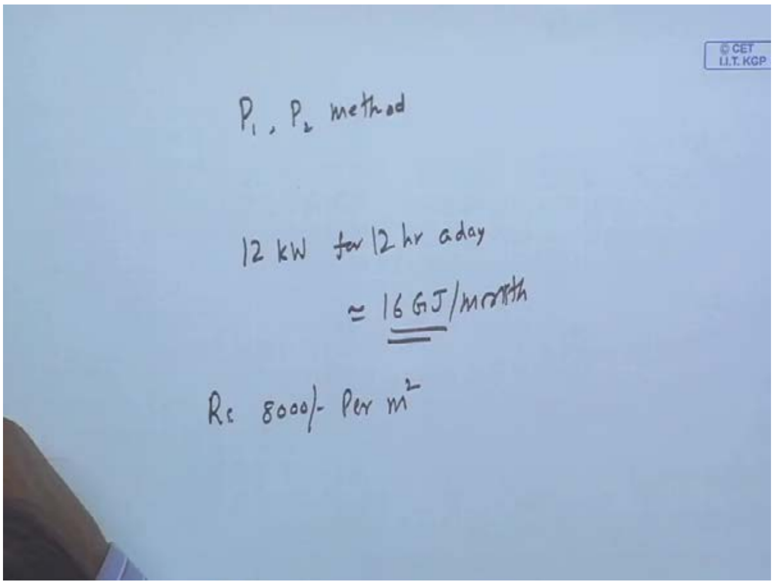

So, this has been actually modeled by Brand Mevlon Brakemen the so called p 1 p 2 method which are the economic indicators one represents the collector loss and other fuel cost and the system cost.

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Fuel	@	Savings 1st Year	Payback Period
Coal	Rs. 3/kg	Rs.18,783	21 Yrs
	Rs. 6/kg	Rs. 37,566	10.5 Yrs
	Rs. 10/kg	Rs. 62,616	6.3 Yrs
LPG	Rs. 35/kg	Rs. 1,26,000	3.17Yrs
Elec.	Rs. 3/kWhr	Rs. 1,05,120	3.8 Yrs
	Rs. 6/kWhr	Rs. 2,10,240	1.9 Yrs

So, I have given typical figures of payback period simple calculation only if you assume to the fuel to be coal at rupees 3 rupees a k g savings per year is so much this corresponds to the system we have discussed 12 kilo watts for 12 hours a day which corresponds to the approximately 16 giga joules per month. So, if I use coal at the certain efficiency of 80 percent and the 70 percent the yearly saving is so much and the payback period is 21 years. And if it is at 6 rupees a k g in comes down of course, to 10.5 years and at rupees 10 per k g it is 6.3 years. And I tried my best apparently the retail coal is not sold at least the place I am staying and I could not get real values and the a cola prices at pit area around 2000 to 2500 and rupees per ton.

So, you have assumed a certain transportation charge per k g 3 rupees to 10 rupees seems to be a reasonable number. So, L P G at the old rate at the 35 rupees a k g it comes to the saving of 1 lakh 26 the payback period is the attractive 3.17 years and if you use electricity at 3 kilo 3 rupee per kilo or whatever which is on the lower side in comes to 3.8 years if it at 6 kilo or whatever something like 200 units and above this comes to only 1.9 years. So, if you compare the solar water heating system supplying or employing flat pit collectors roughly I think I have taken R s 8000 per meter square. So, ministry of non conventional resources they have set up a higher limit upper square limit install cost including the accessories 8000 to 10000 and larger system become little less and. So, if you take a average value of 8000 this is the pay back periods which I had calculated.

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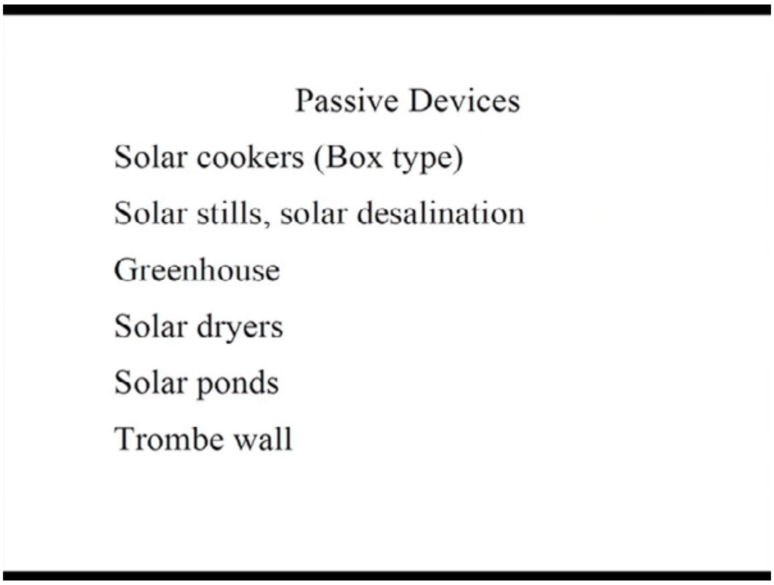

Then we considered passive systems and we also recognized there is no strict demarcation of passive devices and they active devices, but never the less the following like solar cookers.

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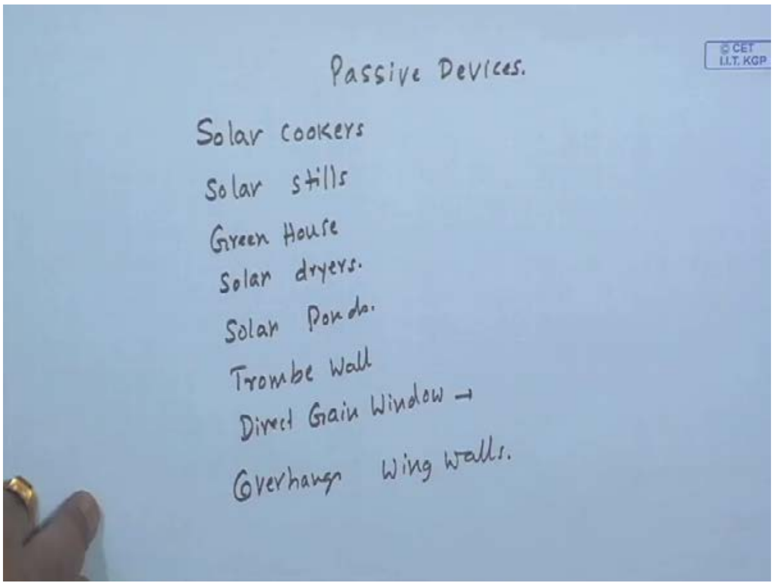

And solar stills this is desalination produces the distill water, Green house this can be used in conjunction with the house to keep the house warmer or plant serving in severe winter or can be used even as a drying mechanism for something like Coffee, Tea, Solar ponds. This is basically the concept of combining the collector and a solar device and then a trombe wall it is basically a wall with an air gape through which air circulates and during the day time it picks up the heat and it warms the room inside and nature circulation bop is set up a direct gain window if you have colder locations a south facing window in the northern hemisphere allows the sun light in winter and does not allow if there is a shade over hung at the shade or that much in summer. So, this can be used for passive heating of the rooms. Then in the context dimension the shading.

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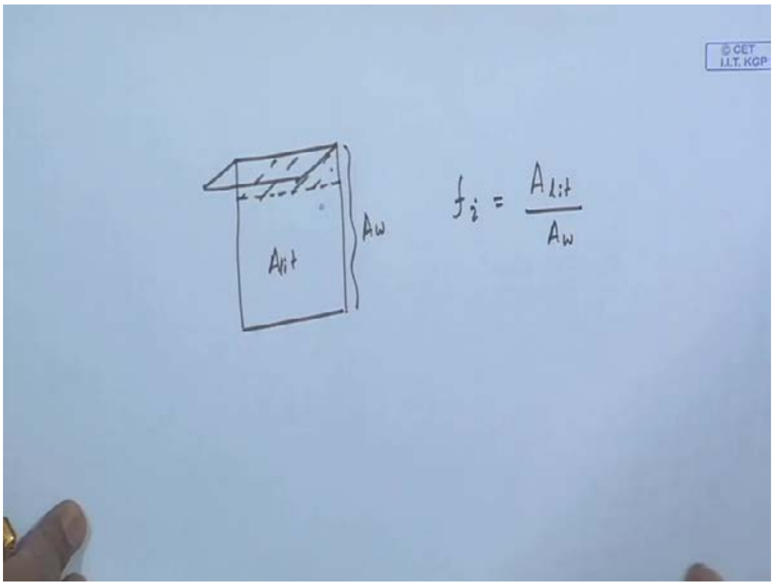

So, that is obtained by corer hangs or wing walls. This is typically if this is a window (( )) over hang like this and it will shad certain part of the window, there will be A lit part; that means, where the solar radiation falls and this is total area is A w the window. So, we define shading factor concept that is what is the total this is f i at any instant is a lit how much of the area of the window is this is the solar radiation let us say, but the total area if a lit is 0 f i is equal to 0 shading factor is 0, if there is no lit area, if it is completely shadowed f i will be 0 and f i will be equal to 1, if it is fully.

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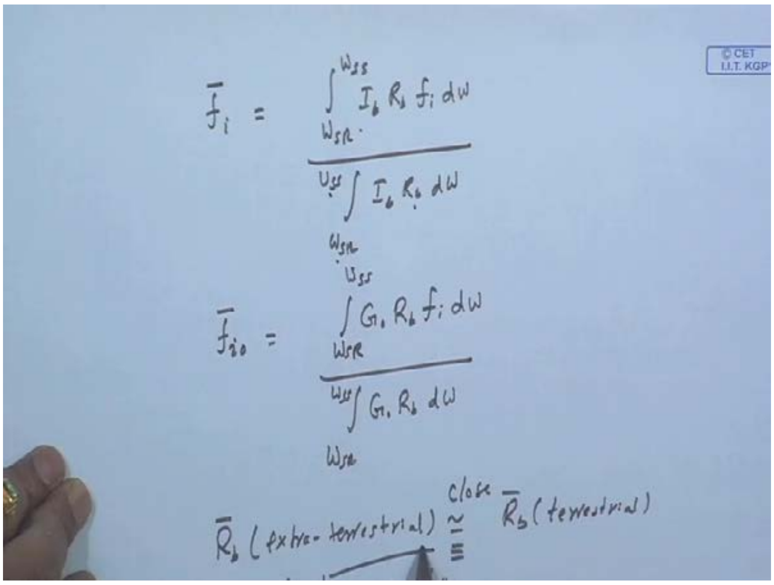

So, average or daily value again has been calculated like we do for the tilt factor for the direct radiation I b R b I f d omega upon I b R b d omega omega S R to omega S S is exactly the if I say f i is equal to 1 it become your I b R b in defining R b bar and expect I remove R b also in the denominator. So, since R b is there I have put omega S R in to omega S S, whereas in the definition of the R b bar, you may recall the denominator is from sun rise to sun set and this can be more easily calculated under extra terrestrial conditions like we have done for R b bar.

And as we argued, why R b bar extra terrestrial is reasonably close R b bar under terrestrial conditions if simply K T is uniform. In fact, it is identical, if K T is uniformed. And approximately reasonably satisfies even if it not and we have the arguments that significant amount of solar radiation is during a certain time period like 10 to 2 or 9 to 3 and the rest of it is there only 10 percent 15 percent of the total daily radiation and during this brighter period the so, pureness index is likely to be uniform. And hence we get the classical result to be a quit close, even if you calculate with the data or assumed defused fraction and distributions.

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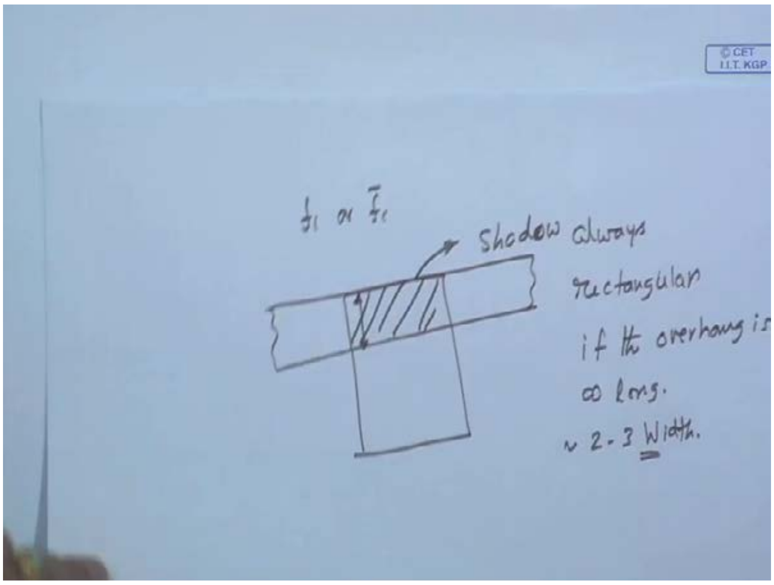

So, we could find a simpler method of calculating f i or f i bar if you have got an infinite k long shadow sorry over hang which will cost the shadow always rectangular if the overhang is infinitely long. So, this may be achieved something like typically 2 to 3 times the width of the window. So, when once that is the cases this only the question of estimating this width depends upon the time of the day.

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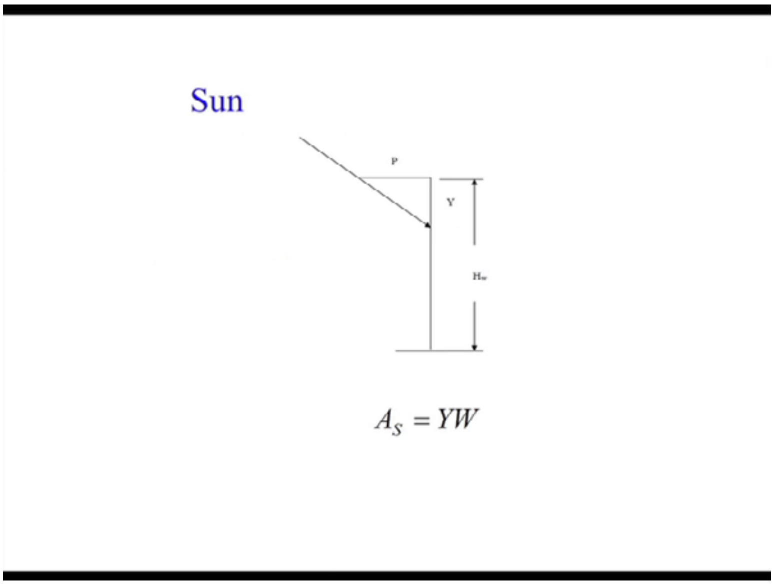

And we can calculate that with the help of the sun's rise A s is Y into W where Y is the shadow depth or height which is again given by this relation Y is equal to p projection by cos theta z by where gamma s is the sun’s azimuthal angle which is again related to cos theta.

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$$I_T A_w = I_b R_b A_{lit} + I_d \left(\frac{1+\cos\beta}{2}\right) A_w + \rho I \left(\frac{1-\cos\beta}{2}\right) A_w$$

$$I_T = I_b R_b f_i + I_d \left(\frac{1+\cos\beta}{2}\right) + \rho I \left(\frac{1-\cos\beta}{2}\right)$$

$$H_T = H_b \overline{R}_b \overline{f}_i + H_d \left(\frac{1+\cos\beta}{2}\right) + \rho H \left(\frac{1-\cos\beta}{2}\right)$$

So, the total solar radiation on the window is pair unit area of the window is I T multiplied by A w should be equal to I b R b A lit into I d into A w and row I into A w then finally, I T there contains a lit by A w giving you f i and if I write it only daily basis you have got A f i bar. So, this is how you can estimate pair unit area of the window, the solar radiation as received even though it is shaded with different shades during different times.

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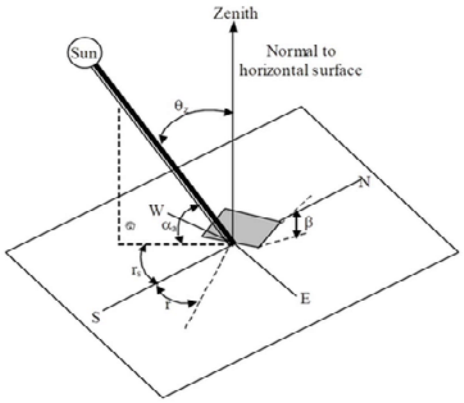

So, this is a old picture that we have recalled to show you the sun's azimuthal angle. Projection of the sun's ray on the horizontal plain this is the projection the deviate on from the north south line is the gamma S the sun's azimuthal angle this is the gamma S.

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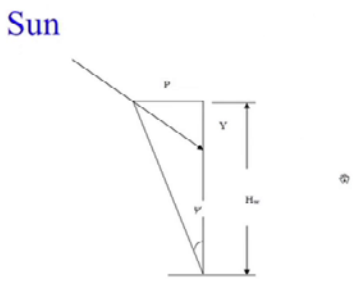
$$A_S = \frac{PW \cos\theta_z}{\cos\theta}$$

$$f_i = 1 - \frac{A_s}{A_w} = 1 - \frac{P\cos\theta_z}{H_w \cos\theta} = 1 - (\tan\psi / R_b)$$



So, f i instantaneous can the bit simple geometry using the previous relation for y is nothing, but a phi is equal to 1 minus tan psi by R b where psi is the angle between a plain that is joining the edge of the overhang to the base of the window.

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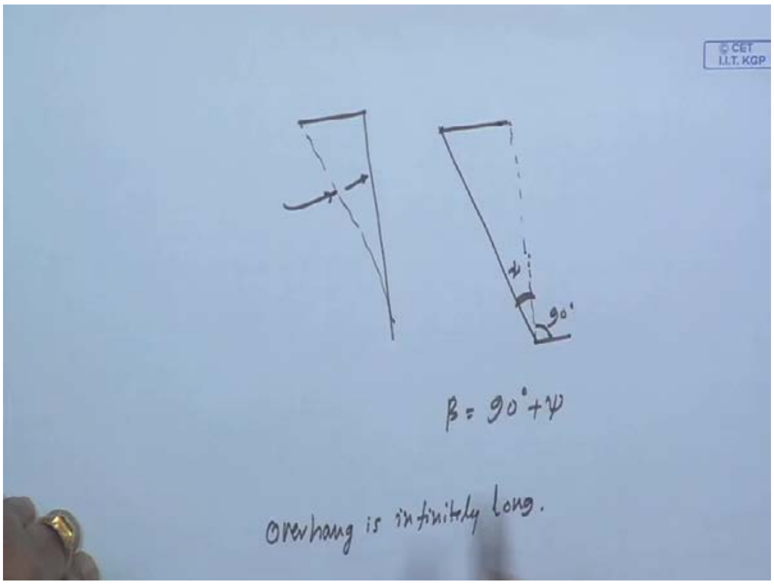

So, the simply optics low is that whatever is the solar radiation entering through the upper chair we reach the sun. So, I will forget about the window and the overhang system. Simply this is psi and this is 90 degrees beta is 90 degrees plus psi. So, this is the tilt surface facing whatever is the azimuthal angle of the window is width a beta equal to 90 plus psi. So, it just you have to evaluate R b bar for that correspondingly you can write down your f i bar infinity in terms of tens I by R b etcetera.

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$$I_b R_b f_i = I_b\left[R_b - tan\,\psi\right] = I_b\left[\frac{A + B\cos\omega + C\sin\omega}{\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta} - \frac{sin\,\psi}{cod\,\psi}\right]$$

$$I_b\left[R_b - tan\,\psi\right] = \frac{I_b}{cod\,\psi}\left[\frac{A^* + B^*\cos\omega + C^*\sin\omega}{\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta}\right]$$

With $\beta^* = \beta + \psi$,

$$A^* = \sin\delta(\sin\phi\cos\beta^* - \cos\phi\sin\beta^*\cos\gamma$$

$$B^* = \cos\delta(\cos\phi\cos\beta^* + \sin\phi\sin\beta^*\cos\gamma$$

$$C^* = \cos\delta\sin\beta^*\sin\gamma$$

So, if you want to calculate a monthly average daily radiation or the f i bar without calculating going through the f i bar to just calculate the daily radiation or the monthly average daily radiation, on the plane which joins edge of the overhang to the base of the window. But this is under the assumption that the over hand is infinitely long. So, essentially, you can rewrite your A star B star and C star in terms of beta star, where beta star is beta plus psi. And these are the standard A B C's for your cos theta expression A plus B cos omega plus C sin omega, which we have used a large number of times. So, this is the tilt factor for the shading plane that is what we call.

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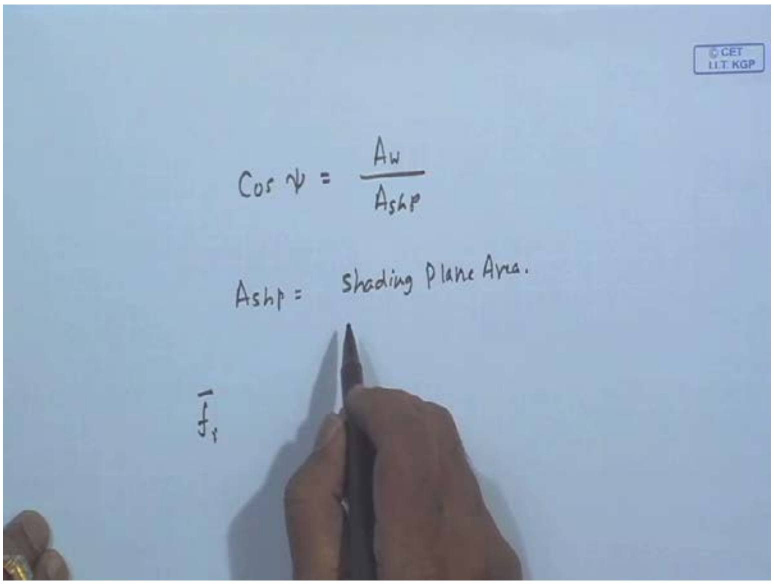

So, if the essentially this cosine sin that angle is nothing but the shading plane window area cos psi by A s h p, A s h p is the shading plane area. So, this is popularly called shading plane concept; its simple optic principle whatever process that just like the pressure drive. So, that is what I have shown here. So, this is the shading plane A s h p, so you can basically, so we shall continue in a short time.